

## CLAIMS

1. An echo processing device for attenuating echo components of a direct signal  $X_{1n}$  in a return signal  $Y_{2n}$ , said device comprising:
  - 5 - means for calculating a receive gain  $Gr_n$  and a send gain  $Ge_n$ ;
  - first gain application means for applying the receive gain  $Gr_n$  to the direct signal and producing an input signal  $X_{2n}$  emitted into an echo generator system; and
  - 10 - second gain application means for applying the send gain  $Ge_n$  to an output signal  $Y_{1n}$  from the echo generator system and producing the return signal  $Y_{2n}$ ;
 said device further comprising means for calculating a coupling variable  $COR$  characteristic of the acoustic coupling between the direct signal  $X_{1n}$  or the input signal  $X_{2n}$  and the output signal  $Y_{1n}$ , said gain calculation means being adapted to calculate the receive gain  $Gr_n$  and the send gain  $Ge_n$  on the basis of
  - 15
  - 20 said coupling variable.
  
2. An echo processing device according to claim 1, comprising means for estimating the instantaneous power of the direct signal  $X_{1n}$  or the input signal  $X_{2n}$  and the instantaneous power of the output signal  $Y_{1n}$ , said gain calculation means being adapted to calculate the receive gain  $Gr_n$  and the send gain  $Ge_n$  on the basis of a variable  $G$  determined as a function of the estimated power of the direct signal or the input signal and the estimated power of the output signal, and as a function of the coupling variable  $COR$ , in accordance with the following equation:

$$G = \frac{P_{2n}}{P_{2n} + COR \cdot P_{1n}}$$

where  $P_{1n}$  and  $P_{2n}$  are respectively an estimate at the

time concerned of the power of the direct signal  $X_{1n}$  or the input signal  $X_{2n}$  and the power of the output signal  $Y_{1n}$ .

- 5    3. An echo processing device according to claim 2, in which the gain calculation means determine the receive gain  $Gr_n$  and the send gain  $Ge_n$  recursively from the following equations:

$$Ge_n = \gamma \cdot Ge_{n-1} + (1 - \gamma) \cdot G$$

$$Gr_n = 1 - \delta \cdot Ge_n$$

- 10    where  $Ge_{n-1}$  is the send gain at the preceding calculation time and  $\gamma$  and  $\delta$  are positive constants less than 1.

- 15    4. An echo processing device according to any one of claims 1 to 3, in which the coupling variable COR is obtained by calculating the correlation between the direct signal  $X_{1n}$  or the input signal  $X_{2n}$  and the output signal  $Y_{1n}$ .

- 20    5. An echo processing device according to claim 4, in which the calculation of the correlation between the direct signal  $X_{1n}$  or the input signal  $X_{2n}$  and the output signal  $Y_{1n}$  is an envelope correlation calculation.

- 25    6. An echo processing device according to claim 5, in which, in said envelope correlation calculation, the coupling variable COR is a function of the maximum value Maxcor of the values  $\text{corr}(j)$  of the correlation between the direct signal  $X_{1n}$  or the input signal  $X_{2n}$  and the output signal  $Y_{1n}$ , said correlation values  $\text{corr}(j)$  being calculated over a time window considered, and each being obtained from the equation:
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$$corr(j) = \frac{\sum_{i=0}^{LM-1} P1(i) \cdot P2(i+j)}{\sum_{i=0}^{LM-1} P1^2(i)}$$

in which i is a sampling time in the calculation time window of duration LM, j is a shift value between the input signal X2n and the output signal Y1n, and P1(t) and P2(t) are respectively an estimate of the power of the direct signal X1n or the input signal X2n and an estimate of the power of the output signal Y1n at a time t.

7. An echo processing device according to claim 6, in which the coupling variable COR is linked to the maximum value Maxcor of the correlation values corr(j) calculated over a calculation time window considered from the equation:

$$COR = Exp(k.Maxcor)$$

in which Exp is the exponential function and k is a positive constant.

8. An echo processing device according to any preceding claim, in which the input signal X2n is emitted into the echo generator system by at least one loudspeaker and the output signal Y1n is obtained from the echo generator system by at least one microphone.

9. An echo processing device according to any one of claims 1 to 8, further comprising an echo canceller receiving at its input said input signal X2n emitted into the echo generator system and the signal Y3n from the echo generator system, the echo canceller comprising a finite impulse response identification

filter whose response is representative of the response of the echo generator system, and the identification filter being adapted to generate a filtering signal  $S_n$  and comprising means for  
 5 subtracting the filtering signal  $S_n$  from the signal  $Y_{3n}$  to produce an output signal  $Y_{1n}$  that is received at the input of said send gain application means.

10. An echo canceller for attenuating in an output signal  
 10  $Y_{1n}$  echo components of an input signal  $X_{2n}$  emitted into an echo generator system, said device comprising:
- a finite impulse response identification filter whose response is representative of the response of the echo generator system, receiving the input signal  
 15  $X_{2n}$  at its input and generating a filtering signal  $S_n$ ;
  - subtraction means receiving at an input a signal  $Y_{3n}$  from the echo generator system, at least one component of which is a response of the echo generator system to the input signal  $X_{2n}$ , and the filtering signal  $S_n$ , and  
 20 adapted to subtract the filtering signal  $S_n$  from the signal  $Y_{3n}$  and to produce the output signal  $Y_{1n}$ ;
  - means for adapting the coefficients of the identification filter as a function of an adaptation step  $\mu_n$ ; and  
 25 - means for calculating the adaptation step  $\mu_n$ , said adaptation step calculation means comprising means for estimating the power  $P_{1n}$  of the input signal  $X_{2n}$  and the power  $P_{3n}$  of the signal  $Y_{3n}$  and means for calculating a first coupling variable  $COR2$   
 30 characteristic of the acoustic coupling between the input signal  $X_{2n}$  and the signal  $Y_{3n}$  from the echo generator system, the adaptation step  $\mu_n$  of the identification filter being calculated as a function of the estimated powers  $P_{1n}$ ,  $P_{3n}$  and as a function of  
 35 the first coupling variable  $COR2$ .

11. A device according to claim 10, in which the adaptation step  $\mu_n$  is obtained from the equation:

$$\mu_n = \frac{P1n}{\alpha \cdot P1n + COR2.P3n}$$

- 5 in which  $\alpha$  is a positive constant and P1n and P3n are respectively an estimate of the power of the input signal X2n and an estimate of the power of the signal Y3n from the echo generator system at the time concerned.

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12. A device according to claim 10 or claim 11, in which the first coupling variable COR2 is obtained by calculating the correlation between the input signal X2n and the signal Y3n.

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13. A device according to claim 12, in which the calculation of the correlation between the input signal X2n and the signal Y3n is an envelope correlation calculation.

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14. A device according to claim 13, in which the first coupling variable COR2 is a function of the maximum value Maxcor2 of correlation values corr2(j) calculated over a time window considered, each of the  
25 correlation values corr2(j) being calculated from the following equation:

$$corr2(j) = \frac{\sum_{i=0}^{LM-1} P1(i) \cdot P3(i+j)}{\sum_{i=0}^{LM-1} P1^2(i)}$$

in which:

$i$  is a sampling time in the calculation time window of duration  $LM$  and  $j$  is a shift value between the input signal  $X2n$  and the signal  $Y3n$ ; and

$P1(t)$  and  $P3(t)$  are respectively an estimate of the  
 5 power of the input signal  $X2n$  and an estimate of the power of the signal  $Y3n$  at the time  $t$  concerned.

15. A device according to claim 14, in which the first coupling variable  $COR2$  is linked to the maximum value  
 10  $Maxcor2$  of said correlation values  $corr2(j)$  by the following equation, in which  $k$  is a positive constant:

$$COR2 = \frac{k}{Maxcor2}$$

16. An echo canceller according to any one of claims 10 to  
 15 15, in which the adaptation step calculation means further comprise means for calculating a second coupling variable  $COR$  characteristic of the acoustic coupling between the input signal  $X2n$  from the echo generator system and the output signal  $Y1n$ , the second  
 20 coupling variable  $COR$  being obtained by calculating the correlation between the input signal  $X2n$  and the output signal  $Y1n$ , and the adaptation step  $\mu_n$  of the identification filter being calculated as a function of the second coupling variable  $COR$ .

25 17. An echo canceller according to claim 16, in which the second coupling variable  $COR$  is obtained from an envelope correlation calculation between the input signal  $X2n$  and the output signal  $Y1n$ .

30 18. An echo canceller according to claim 17, in which the second coupling variable  $COR$  is a function of the maximum value  $Maxcor$  of the values  $corr(j)$  of the

correlation between the input signal  $X2n$  and the output signal  $Y1n$ , said correlation values  $corr(j)$  being calculated over a time window considered and each of them being obtained from the equation:

$$corr(j) = \frac{\sum_{i=0}^{LM-1} P1(i) \cdot P2(i+j)}{\sum_{i=0}^{LM-1} P1^2(i)}$$

in which  $i$  is a sampling time in the calculation window of duration  $LM$ ,  $j$  is a value of a shift value between the input signal  $X2n$  and the output signal  $Y1n$ , and  $P1(t)$  and  $P2(t)$  are respectively an estimate of the power of the input signal  $X2n$  and an estimate of the power of the output signal  $Y1n$  at a time  $t$ .

19. An echo canceller according to any one of claims 16 to 18, characterized in that the adaptation step  $\mu_n$  is calculated from the equation:

$$\mu_n = \frac{COR}{COR2} \cdot \frac{P1n}{\alpha \cdot P1n + COR2 \cdot P3n}$$

in which  $\alpha$  is a positive constant and  $P1n$  and  $P3n$  are respectively an estimate of the power of the input signal  $X2n$  and an estimate of the power of the signal  $Y3n$  from the echo generator system at the time concerned.

20. An echo processing device according to claim 9, in which the echo canceller is according to any one of claims 10 to 15, the adaptation step  $\mu_n$  of the identification filter being calculated as a function of the estimated power  $P1n$  of the direct signal  $X1n$  or the input signal  $X2n$ , the estimated power  $P3n$  of the signal  $Y3n$  from the echo generator system, and said

coupling variable COR2.

21. An echo processing device according to claim 9, in which the echo canceller is according to any one of  
 5 claims 16 to 19, the adaptation step  $\mu_n$  of the identification filter being calculated as a function of the estimated power  $P_{1n}$  of the direct signal  $X_{1n}$  or the input signal  $X_{2n}$ , the estimated power  $P_{3n}$  of the signal  $Y_{3n}$  from the echo generator system, and said  
 10 coupling variable COR, COR2.

22. An echo processing device for a multichannel communications system comprising N receive channels, N being an integer greater than or equal to 2; and M  
 15 send channels, M being an integer greater than or equal to 1, each of the N receive channels i comprising an output transducer ( $LS_i$ ) that produces a sound pressure wave in response to an input signal  $X_{2n}(i)$  derived from a direct signal  $X_{1n}(i)$ , each of  
 20 the M send channels j comprising an input transducer ( $MC_j$ ) that converts a sound pressure wave into an output signal  $Y_{1n}(j)$ , said echo processing device being adapted to attenuate in each output signal  $Y_{1n}(j)$  echo components stemming from some or all of  
 25 the N input signals  $X_{2n}(i)$  and resulting from the acoustic coupling between the input transducer of the send channel concerned and some or all of the M output transducers, said device being characterized in that it comprises:

- 30 - means for calculating receive gains  $Gr_n(i)$  and send gains  $Ge_n(j)$ ;
- means for applying receive gains  $Gr_n(i)$  to each direct signal  $X_{1n}(i)$  and producing the corresponding input signal  $X_{2n}(i)$ ;
- 35 - means for applying send gains  $Ge_n(j)$  to each output



signal  $Y1n(j)$  and producing the corresponding return signal  $Y2n(j)$ ; and

- means for calculating, for each send channel  $j$ ,  $N$  coupling variables  $COR(j,i)$ , for  $i$  varying from 1 to  $N$ , each of which being characteristic of the acoustic coupling between the output signal  $Y1n(j)$  of the send channel and one of the  $N$  input signals  $X2n(i)$ ;  
 said gain calculation means being adapted to calculate each receive gain  $Gr_n(i)$  and each send gain  $Ge_n(j)$  on the basis of the  $N$  coupling variables  $COR(j,i)$  calculated for the associated send channel  $j$ .

23. A device according to claim 22, comprising means for estimating the instantaneous power  $P1n_i$  of each input signal  $X2n(i)$  and the instantaneous power  $P2n_j$  of each output signal  $Y1n(j)$ , said send gain calculation means being adapted to calculate each send gain  $Ge_n(j)$  on the basis of  $N$  variables  $G(j,i)$ , for  $i$  varying from 1 to  $N$ , each of which is determined as a function of the estimated power of an input signal  $X2n(i)$  and the estimated power of the output signal  $Y1n(j)$  of the send channel concerned and as a function of the corresponding coupling variable  $COR(j,i)$ , each of the variables  $G(j,i)$  being obtained from the following equation:

$$G(j,i) = \frac{P2n_j}{P2n_j + COR(j,i) \cdot P1n_i}$$

in which  $P1n_i$  and  $P2n_j$  are respectively an estimate of the power of the input signal  $X2n(i)$  concerned and an estimate of the power of the output signal  $Y1n(j)$  concerned at the time concerned.

24. A device according to claim 23, in which each send gain  $Ge_n(j)$  is determined from the minimum value of the

N variables  $G(j,i)$ , for  $i$  varying from 1 to N, calculated for the associated send channel  $j$ .

25. A device according to claim 24, in which each send  
5 gain  $Ge_n(j)$  is determined from the equation:

$$Ge_n(j) = \gamma \cdot Ge_{n-1}(j) + (1 - \gamma) \cdot \min_i(G(j,i))$$

in which  $Ge_{n-1}(j)$  is the send gain of the send channel  
 $j$  at the time of the preceding calculation,  $\gamma$  is a  
positive constant less than 1, and  $\min_i(G(j,i))$  is the  
10 minimum value of the N variables  $G(j,i)$  for  $i$  varying  
from 1 to N.

26. A device according to claim 25, in which all the  
receive gains  $Gr_n(i)$  have the same value, which is  
15 determined from the equation:

$$Gr_n(i) = 1 - \delta \cdot \max_j(Ge_n(j))$$

in which  $\delta$  is a positive constant less than 1 and  
 $\max_j(Ge_n(j))$  is the maximum value of the M send gains  
 $Ge_n(j)$ , for  $j$  varying from 1 to M.

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27. A device according to any one of claims 22 to 25, in  
which each of said receive gains  $Gr_n(i)$  is equal to 1.

28. A device according to any one of claims 22 to 27, in  
25 which each coupling variable  $COR(j,i)$  is obtained by  
calculating the correlation between the corresponding  
output signal  $Y1n(j)$  and the corresponding input  
signal  $X2n(i)$ .

- 30 29. A device according to claim 28, in which the  
calculation of the correlation between an output  
signal  $Y1n(j)$  and an input signal  $X2n(i)$  is an  
envelope correlation calculation.

30. A device according to claim 29, in which, in said envelope correlation calculation, each coupling variable  $COR(j,i)$  is a function of the maximum value  
 5 Maxcor of the values  $corr_{ji}(d)$  of the correlation between the output signal  $Y1n(j)$  and the input signal  $X2n(i)$ , said correlation values  $corr_{ji}(d)$  being calculated over a predefined time window and each obtained from the equation:

$$10 \quad corr_{ji}(d) = \frac{\sum_{c=0}^{LM-1} P1n_i(c) \cdot P2n_j(c+d)}{\sum_{c=0}^{LM-1} P1n_i^2(c)}$$

in which  $\underline{c}$  is a sampling time in the calculation time window of duration LM,  $\underline{d}$  is a shift value between the input signal  $X2n(i)$  and the output signal  $Y1n(j)$ , and  $P1n_i(t)$  and  $P2n_j(t)$  are respectively an estimate of the  
 15 power of the input signal  $X2n(i)$  and an estimate of the power of the output signal  $Y1n(j)$  at a time  $\underline{t}$ .

31. An echo canceller for a multichannel communications system comprising N receive channels, N being an  
 20 integer greater than or equal to 2, and M send channels, M being an integer greater than or equal to 1, each of the N receive channels  $\underline{i}$  comprising an output transducer (LSi) that produces a sound pressure wave in response to an input signal  $X2n(i)$ , and each  
 25 of the M send channels  $\underline{j}$  comprising an input transducer (MCj) that converts a sound pressure wave into an output signal  $Y1n(j)$ , the echo canceller comprising:

- for each send channel  $\underline{j}$ , N identification filters  
 30  $F_{ij}$  with variable coefficients for estimating the acoustic coupling between each of the N output

transducers (LS<sub>i</sub>) and the input transducer (MC<sub>j</sub>) of the send channel j, and

- for each filter F<sub>ij</sub>, means for adapting the coefficients of the filter as a function of an adaptation step  $\mu_n(i,j)$  and means for calculating the adaptation step  $\mu_n(i,j)$ ,

- means for estimating the instantaneous power P1n<sub>i</sub> of each input signal X2n(i) and the instantaneous power P2n<sub>j</sub> of each output signal Y1n(j), and

- means for calculating, for each send channel j, N coupling variables COR(j,i), for i varying from 1 to N, each of which being characteristic of the acoustic coupling between the output signal Y1n(j) of the send channel j and one of the N input signals X2n(i),

the means for calculating the adaptation step  $\mu_n(i,j)$  for a filter F<sub>ij</sub> associated with a receive channel i and a send channel j being adapted to calculate the adaptation step  $\mu_n(i,j)$  as a function of the powers P1n<sub>i</sub>, for i varying from 1 to N, estimated for the N receive channels, as a function of the estimated power P2n<sub>j</sub> of the send channel j, and as a function of the N coupling variables COR(j,i), for i varying from 1 to N, associated with the send channel j.

32. A device according to claim 31, in which an adaptation step  $\mu_n(i,j)$  for a filter F<sub>ij</sub> associated with a receive channel i and a send channel j is obtained from the following equation, in which b<sub>i</sub> is a positive constant:

$$\mu_n(i,j) = \frac{P1n_i}{b_i \cdot P1n_i + COR(j,i) \cdot P2n_j + \sum_{k \neq i} COR(j,k) \cdot P1n_k}$$

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33. A device according to claim 31 or claim 32, in which a coupling variable COR(j,i) is obtained by calculating the correlation between the output signal Y1n(j) and

the input signal  $X2n(i)$ .

34. A device according to claim 33, in which the calculation of the correlation between the output  
5 signal  $Y1n(j)$  and the input signal  $X2n(i)$  is an envelope correlation calculation.

35. A device according to claim 34, in which the coupling  
10 variable  $COR(j,i)$  is a function of the maximum value  $Maxcor(j,i)$  of the correlation values  $corr_{ji}(d)$ , calculated over a time window considered, each of the correlation values  $corr_{ji}(d)$  being calculated from the equation:

$$corr_{ji}(d) = \frac{\sum_{c=0}^{LM-1} P1n_i(c) \cdot P2n_j(c+d)}{\sum_{c=0}^{LM-1} P1n_i^2(c)}$$

15 in which  $\underline{c}$  is a sampling time in the calculation time window of duration  $LM$ ,  $\underline{d}$  is an offset between the input signal  $X2n(i)$  and the output signal  $Y1n(j)$ , and  $P1n_i(t)$  and  $P2n_j(t)$  are respectively an estimate of the power of the input signal  $X2n(i)$  and an estimate of  
20 the power of the output signal  $Y1n(j)$  at a time  $\underline{t}$ .

36. A device according to claim 35, in which the coupling  
variable  $COR(j,i)$  is linked to the maximum value  $Maxcor(j,i)$  of said correlation values  $corr_{ji}(d)$  by the  
25 following equation, in which  $\underline{k}$  is a positive constant:

$$COR(j,i) = \frac{k}{Maxcor(j,i)}$$

37. A device according to any one of claims 31 to 36, in which each filter  $Fij$  associated with a receive

channel i and a send channel j generates a filtering signal that is subtracted from the output signal  $Y1n(j)$  to provide a filtered signal  $Y2n(j)$ ,  
 said device further comprising means for calculating,  
 5 for each send channel j, N second coupling variables  $COR2(j,i)$ , for i varying from 1 to N, each of which being characteristic of the acoustic coupling between the filtered signal  $Y2n(j)$  from the send channel and one of the N input signals  $X2n(i)$ , the adaptation step  
 10  $\mu_n(i,j)$  of an identification filter  $Fij$  associated with a receive channel i and a send channel j being calculated as a function of said N second coupling variables  $COR2(j,i)$ .

15 38. A device according to claim 37, in which an adaptation step  $\mu_n(i,j)$  for a filter  $Fij$  associated with a receive channel i and a send channel j is obtained from the following equation, in which  $b_i$  is a positive constant:

$$\mu_n(i,j) = \frac{COR(j,i)}{COR2(j,i)} \cdot \frac{Pln_i}{b_i \cdot Pln_i + COR(j,i) \cdot P2n_j + \sum_{k \neq i} COR(j,k) \cdot Pln_k}$$

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39. A device according to claim 37 or 38, further comprising, for each pair comprising a receive channel i and a send channel j, gain application means for applying a receive gain  $Gr_n(i)$  to the input signal  
 25  $X2n(i)$  and a send gain  $Ge_n(j)$  to the filtered signal  $Y2n(j)$ , said gains  $Gr_n(i)$ ,  $Ge_n(j)$  being calculated on the basis of the N second coupling variables  $COR2(j,i)$  determined for the send channel j.